THE STATUS OF FGD TECHNOLOGY, AND ITS PROSPECTS IN COAL-FIRED POWER PLANTS IN SICHUAN PROVINCE

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ABSTRACT

Coal with high sulfur content is very popular in Sichuan Province. Because meteorological conditions in the Sichuan Basin do not favor diffusion, Sichuan Electric Power Corporation (SEPC) takes many measures to control SO_2 pollution and acid rain to protect the environment. In the last 20 years, a desulfurization base with distinctive features has been formed in Sichuan. Many desulfurization tests have been conducted, and pilot plants using different technologies have been developed and constructed; also, many engineering and technical personnel have been trained in desulfurization, and have helped establish manufacturers of desulfurization equipment. This article discusses the background and main achievements of desulfurization technologies in coal-fired power plants in Sichuan Province, as well as the future prospects for desulfurization in the new century.

1) INTRODUCTION

Sichuan Province is located in southwestern China, near the upper reaches of the Yangtze River; it has a population of 82,600,000 and an area of 485,000 km^2. The terrain of Sichuan is complicated and diverse; the 5 main landforms are Sichuan Basin: Qinzhang Plateau, Hengduan Mountain Area, Yungui Plateau, and Qinba Mountainous Region, and the region features lots of mountains and rivers co-existing with basins and plateaus. Inside Sichuan Province, there are the Yangtze River and its tributaries, the Jialing, Minjiang, Tuojiang, Yalong and Dadu Rivers. Gongga Mountain is the highest mountain in the province, with a maximum elevation of 7,556 m. In most areas, annual rainfall is 800–1,200 mm, and average annual temperature is 15–19 C (Figure 1).

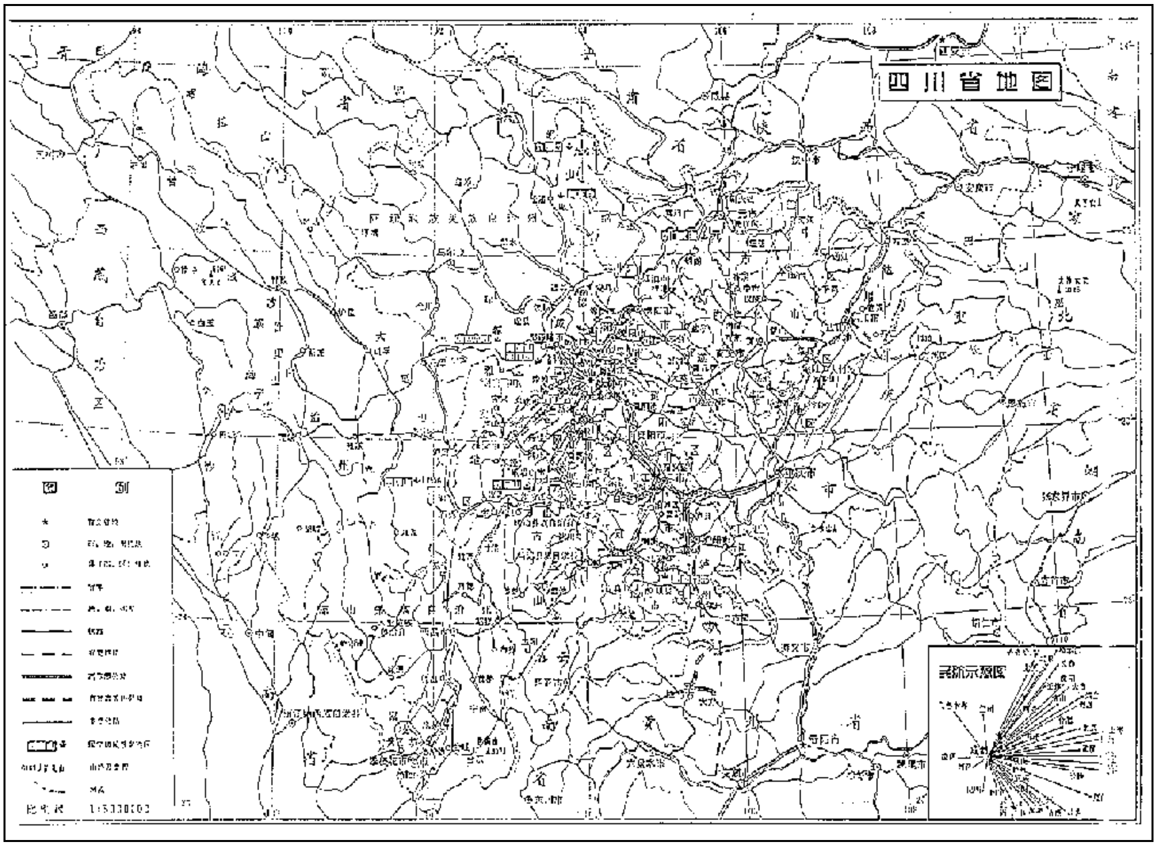

Figure 1. Map of Sichuan Province

The existing installed capacity of Sichuan Province is 16,000 MW; of this, 8,680 MW is hydro and 7,320 MW is thermal. The installed capacity of the SEPC is 7,430 MW, and of this, 5 hydro power stations generate 3,010 MW, while 9 coal-fired power plants (including those with a majority of shares controlled or partly owned by SEPC) generate 4,420 MW. In order to adjust the structure of the electricity industry, optimize the disposal of resources, protect the environment and save energy, 34 small coal-fired power plants with a total installed capacity of 1,150 MW will be shut down between 1999 and 2004. In this way, the pollution caused by wastewater and gas from these power plants will be alleviated.

About 30% of raw coal produced in Sichuan is used as fuel in coal-fired power plants. Annual SO_2 emissions from the plants owned by SEPC amount to 240,000 tons because of low coal quality, and high ash and sulfur content. The pollution of SO_2 causes severe acid rain and a decline in environment quality in some areas of Sichuan Province.

With support from the National Planning Commission and State Electric Power Corporation (formerly the Ministry of Electric Power Industry), SEPC has conducted many tests and popularized different desulfurization technologies. Now, Sichuan Province is an example base for different flue-gas-desulfurization (FGD) technologies in China. Systems that have been put into operation include:

- a circulating fluidized bed combustion (CFBC) boiler (410 t/h) at Neijiang Gaoba Thermal Power Plant;

- an Electron Beam Ammonia FGD Pilot Plant with a treatment capacity of 300,000 Nm^3/h at Chengdu Thermal Power Plant;
- a Limestone-Gypsum FGD System at Luohuang Thermal Power Plant;
- a pilot plant of Semi-Dry Spinning-Spray FGD at Baima Thermal Power Plant; and,
- an Ammonium Phosphate Fertilizer FGD Process (PAFP) at Douba Thermal Power Plant.

Also being undertaken is:

- preparation of a 100-MW CFBC Boiler (manufactured in China), and retrofitting of a Semi-Dry-Type Gas-Phase-Suspension Absorbing Desulfurization Process at the 200-MW units at Baima Thermal Power Plant; and,
- tests on Gas-Liquid-Solid-Phase Fluidized Bed Desulfurization technologies at Huayinshan Thermal Power Plant, and on Ammonia-based FGD technology at Baima Thermal Power Plant.

In the future, implementation of air pollution control laws, the 9th Five-Year Plan for the National Economy and Social Development, and the Outline of Objectives in 2010 will further enhance control of SO_2 emissions, and will raise the FGD technology of coal-fired power plants in Sichuan to a higher level.

2) CHARACTERISTICS OF COAL AND SO_2 POLLUTION

Sichuan has rich coal resources. Proven coal deposits are about 11 billion tons, and guaranteed deposits are about 10 billion tons (including the deposit in the former Chongqing Area. Among these, about 50% is anthracite, and others are coking coal, lean coal and brown coal, etc. Generally, the coal in Sichuan is of low quality; very little coal is of high quality with low sulfur content. Ash content is normally 15–50% (some can reach 70%), sulfur content is normally 2–5%, and there is very little coal with 1% sulfur content. Because most sulfur in coal is of sulfuret (very little is of organosulfur) it is very difficult to remove the sulfur by washing.

Annual consumption of raw coal in coal-fired power plants owned by SEPC is about 8.658 million tons (mmt), with average sulfur content of 2%. In southern Sichuan (Neijiang City and Yibin City), there is installed capacity of 1,450 MW, and annual coal consumption is 3.469 mmt, representing 40.1% of total coal consumption in Sichuan. The coal for coal-fired power plants in this area is mainly supplied by Furong Coal Mine and Huayinsannanduan Coal Mine. The coal from Furong Coal Mine is of high or extra-high sulfur content, with volatile content of 6–14%, ash content of 25–30%, and sulfur content of 3–5%. The coal from Huayinsannanduan Coal Mine is of high sulfur content with volatile content of 13–44%, ash content of 25–40%, and sulfur content of 3%. The total installed capacity of Chengdu Thermal Power Plant and Jiangyou Thermal Power Plant in western Sichuan is 985 MW, with annual coal consumption of2.636 mmt, representing 30.3% of total coal consumption in Sichuan. The coal for these two power plants is mainly a mixture of coal from the Guangwang Coal Mine and other coal mines, with volatile content of 14–44%, ash content of 15–67% (normally 20–35%), and sulfur content of 0.2–2.5% (normally 0.4–1%); this coal is of low sulfur content.

The total installed capacity of coal-fired power plants in the Panzihua Area is 336 MW with annual raw-coal consumption of1.296 mmt. The coal is supplied by local coal mines

with volatile content of 19–24%, ash content of 5–69%, and sulfur content of 0.2–2.0% (normally 0.5–1%); this coal is of low sulfur content. The installed capacity of Huayinsan Thermal Power Plant in eastern Sichuan is 300 MW, with annual coal consumption of 790,000 tons. The coal is supplied by Huayinsannanduan Coal Mine with a sulfur content of 3.3%. The coal for Wutongqiao Thermal Power Plant (2x50 MW) in southern Sichuan is supplied by coal mines in the Lesan Area, with average sulfur content of 0.8%. The coal for Guanan Thermal Power Plant, which will be put into service soon, also will be from Huayinsannanduan Coal Mine, with a sulfur content of 2.9%. Except for the coal-fired power plants in the Panzihua Area and western Sichuan, the coal for power plants owned by SEPC is of high and normal (2.9–5%) sulfur content, with the high-sulfur coal taking more than half of total coal consumption at SEPC coal-fired power plants.
Except for a small amount of raw coal used for coking, most raw coal produced in Sichuan is used for burning, emitting SO_2 directly into the air. It is estimated that more than 90% of annual SO_2 emissions of 1 mmt are from the burning of coal. Sichuan Basin is a "closed" basin with low wind velocity, high humidity, frequent clouds and fog, and little sunshine. This results in a meteorological environment that does not favor diffusion or dispersal of pollutants; this environment and the combustion of low-quality coals, makes Sichuan one of the main acid rain areas in China.
Monitoring results from the Environmental Protection Authority show that acid rain appears mainly in Sichuan Basin and its neighboring areas, among which the corridors from Neijiang to Yibin, and Yibin to Chongqing are most severe. Among the Acid Rain Control Areas designated by the State Council, 14 cities and areas of Sichuan, including Chengdu, Neijiang and Yibin, are included. The Acid Rain Control Area in Sichuan Province is about 110,000 km^2, or 22.7% of the total area in Sichuan; it contains 76.5% of Sichuan's population, amidst 86.4% of allSO_2 emissions. Except for Huayinsan Thermal Power Plant, the coal-fired power plants of Sichuan are located inside Acid Rain Control Areas.
Coal quality and acid rain present severe challenges to the development of Sichuan's Power Industry, because many of the principal coal-fired power plants are located in areas of high-sulfur coal, and fuel for the coal-fired power plants is mainly local raw coal. With the development of cities and upgrading of public facilities, more and more natural gas and electrical appliances for residences have replaced small boilers and honeycomb briquets. Now, coal-fired power plants have become the main source of SO_2 emissions. Even though the quantity of emissions is not large, the emissions are relatively concentrated, and high emission height causes transmission of SO_2 to far places, enlarging the scope of acid rain. This is one of the main factors affecting the air quality of Sichuan Basin; big SO_2 emission sources are in Yibin, Neijiang, Chengdu, Jiangyou, Guangan, and Panzihua, and emission heights are normally 150–240m. Additional new 884-MW power-generating units will be put into service, causing 100,000 more tons of SO_2 emissions each year. If SO_2 emission control measures are not adopted, the acid rain area in Sichuan will be further enlarged, the borders of that area will move north, and the rain in neighboring areas of Sichuan Basin will be also effected by SOx and NOx.
In such a severe situation, in order to protect the ecology and environment of the area, and promote economical construction, the control of SO_2 emissions must be speeded up.

3) CURRENT SITUATION FOR DESULFURIZATION TECHNOLOGIES

The control technologies for SOx emissions from coal-fired power plants developed in advanced countries are mainly of three types:

- Clean coal combustion represented by washing coal, selecting coal and gasification of coal;
- Desulfurization during the combustion process represented by CFBC and PFBC;
- Flue Gas Desulfurization (FGD).

In Sichuan, extensive and thorough research and development has been carried out on FGD, and relevant pilot and example plants have been built. A 410-t/h CFBC example system has been built, and upgrading and verification work are being undertaken. Now, most coal for coal-fired power plants is raw, unwashed coal. Even though coal-washing technology with the objective of getting rid of sulfur and ash in coal has been used at the Chongqing Thermal Power Plant (formerly controlled by SEPC), it has not been popularized because the effect is not very good.

3.1 Circulating Fluidized Bed Combustion (CFBC)

CFBC is a new technology developed in recent decades, allowing desulfurization and DeNOx to be realized inside the furnace, a major innovation for traditional pulverized-coal boilers. It is also an effective way to solve the environmental pollution problem while producing power. Coal for the coal-fired power plants in the Neijiang Area (from Furong Coal Mine and Huayinsannanduan Coal Mine) has high sulfur content (3–5%), high ash content (25–40%), low volatile content (minimum 6%), low heating value (4100 Kcal/kg) and a low ash melting point. Because of this, CFBC is an ideal solution for the combustion of this coal.

In 1992, one 410-t/h CFBC boiler was imported from Finland by the Chinese government to serve as a national example project; it was built in Sichuan Province and christened the Neijiang Gaoba Thermal Power Plant. The unit was first operated in April 1996, and put into commercial operation in September 1996. According to the contract, comprehensive technical performance testing of the boiler was finished in March 1998. The main technical specifications are as follows:

Item	Guaranteed value of the contract	Testing value
MCR steam flow	113.9 ± 5.2 kg/s	110.9kg/s
Main steam temperature (@ 60%–100% load)	540 ± 5	537.5
Efficiency of boiler (100 MCR) DeSOx Ratio (Ca/S) SOx emission concentration NOx emission concentration CO emission concentration	90.7% 2.225 700mg/Nm^3 200mg/Nm^3 250mg/Nm^3	90.79% 2.219 684mg/Nm^3 78mg/Nm^3 211mg/Nm^3

Testing and operation results for the boiler show:

- stable combustion, high efficiency, easy operation and high reliability;

- a strong ability to be loaded, wide load-adjustment range, good performance following a change of load, and strong ability to change load at low loads, with a minimum load that keeps stable combustion able to be controlled at 30–35% without combustion-supporting oil;
- a high level of automation, with starting and stopping of the boiler and adjustment of combustion fully controlled by computer. Ten hours is enough from cold-starting of boiler to being fully loaded. Warm starting is faster, requiring only about 2 hours from starting to being fully loaded;
- an operating temperature that can be controlled at 850–900 C. When limestone is injected, Ca/S is 2.2, desulfurization efficiency can be 90%, SOx emission concentration can be lower than 700 mg/Nm^3, and NOx emission concentration can be lower than the design value of 200mg/Nm^3.

The 410-t/h CFBC boiler at Neijiang Gaoba is the most advanced in the world, consisting of a water-steam system, an air-flue gas system, a coal-limestone system, a combustion system, and a dust-removal system. The suited condensing turbine-generator is manufactured by Beijing Heavy Electric Equipment Works.

The control system for the boiler generating unit is an advanced Distributed Central Control System (DCS) with a high level of automatic control. The coal is mainly anthracite from southern Sichuan, with sulfur content of 3–4%, and ash content of 20–30%. The desulfurization agent is local limestone, and the CaO content in the quicklime is 83% after being roasted.

3.2 Electron Beam Ammonia FGD Technology (EBA)

Electron Beam ammonia FGD is a dry flue-gas-treatment technology, using an electron beam with high energy to irradiate the flue gas, removing SOx and NOx simultaneously, and producing a byproduct of nitrogen fertilizer (a mixture of ammonium sulfate ($[NH_4]_2SO_4$) and ammonium nitrate (NH_4NO_3); this is one kind of FGD technology with no waste water or waste residue.

In order to jointly develop the technology, the SEPC and EBARA Corporation (Japan) signed a contract in Oct 1995 to construct a pilot project using EBA at the Chengdu Thermal Power Plant. Construction began in March 1996 and finished in September 1997; the plant is operating, and tests of the germination and growing performance of the fertilizer byproduct (a mixture of ammonium sulfate $(NH_4)_2SO_4$ and ammonium nitrate (NH_4NO_3) have been finished, and a cultivation test is being carried out on the field.

The EBA desulfurization plant at Chengdu is the largest of this technology in the world. Its designed flue-gas treatment capacity is 300,000 Nm^3/h. The main technologies are a flue-gas cooling system, an ammonia supply system, an electron beam irradiating system, and a byproduct separating and collecting system. The flue gas enters the cooling tower after the byproduct collector (ESP), and its temperature drops to 60–65 C, which is suitable for desulfurization. The flue gas then enters a reactor under the irradiation of a high-energy electron beam, and N_2, O_2 and H_2O in the flue gas change into the free radicals OH, O, HO_2, and N, which are very active. The free radicals oxidize SO_2 and NO_2 in the flue gas into sulfuric acid (H_2SO_4) and nitric acid (HNO_3) (Figure 4); then, sulfuric and nitric acid change into ammonium sulfate and ammonium nitrate when they mix with gaseous ammonia injected at the front of the reactor. When the flue gas enters another ESP byproduct, ammonium sulfate and ammonium nitrate are collected as byproduct. A booster fan forces the clean flue gas into an (exhaust) stack and then into the air.

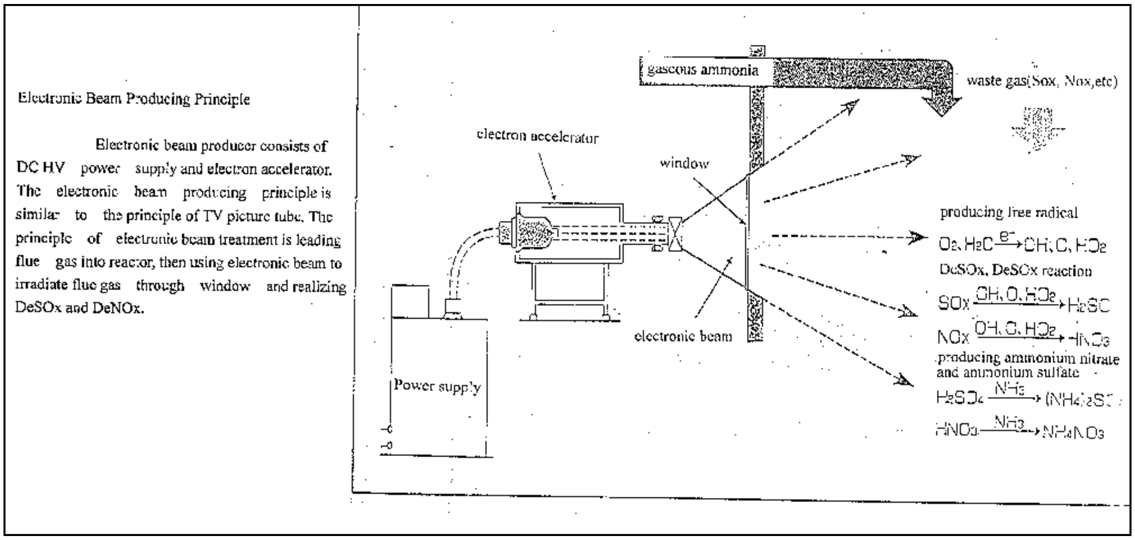

Figure 4. Diagram of Electron Beam Irradiation

If the SO_2 concentration at the inlet of the FGD system is 1800 ppm, the main technical parameters are as follows: desulfurization efficiency is 80%, DeNOx efficiency is 10%, liquid ammonia consumption is 654 kg/h, electricity consumption is 1900 kw/h, production of the byproduct ammonium sulfate is 2340 kg/h, and production of ammonium nitrate is 20 kg/h. Thus the actual testing results are higher than the design values.

Two years of operating results show that the plant is simple and compact, easy to operate, requires only a small space, and produces useful byproducts. Compared with other FGD technologies, there is no secondary pollution from byproducts, and DeNOx and desulfurization can be realized simultaneously. The drawbacks of byproducts staining the positive and negative plates of the ESP, and corrosion of equipment caused by byproducts, should be solved in the future.

Operation of the pilot plant shows that it is feasible to enlarge the technology from a treatment capacity of 12,000 Nm^3/h to the current capacity of 300,000 Nm^3/h. The half-finished cultivation test shows the byproduct is harmless to crops and is equivalent in effect to nitrogen fertilizer. It is planned to finish the cultivation test and get a fertilizer license for the byproduct in the first half of next year.

<u>3.3 Ammonium Phosphate Fertilizer FGD Process (PAFP)</u>

PAFP is an FGD technology that uses natural phosphate rock and ammonia as raw materials, and produces the byproduct ammonium phosphate compound fertilizer during the activated carbon desulfurization process. In 1990, a pilot PAFP system with a flue-gas treatment capacity of 5000 Nm^3 /h was built at the Douba Thermal Power Plant in Sichuan Province. The flue gas comes from a 410-t/h wet-bottom boiler with an inlet SO_2 concentration of 2000–3000ppm. The PAFP process consists of the following operating units: adsorbing, extraction, neutralization, absorbing, oxidization, concentration and drying etc. (Figure 5). The pilot system consists of 4 main processes: primary desulfurization using activated carbon and getting 30% dilute sulfuric acid; dilute sulfuric acid extracting phosphate rock and getting phosphoric acid with a concentration of more than 10%; secondary desulfurization using a neutralization solution of phosphoric acid and ammonia $(NH_4)_2HPO_4$; and concentrating and drying the thick liquid and getting ammonium phosphate compound fertilizer. The efficiency of primary desulfurization is 70–80%, and total efficiency of the system is 95%. The fertilizer grade of the byproduct $(N+P_2O_5)$ is more than 35%, which means the byproduct can be used as a fertilizer for crops.

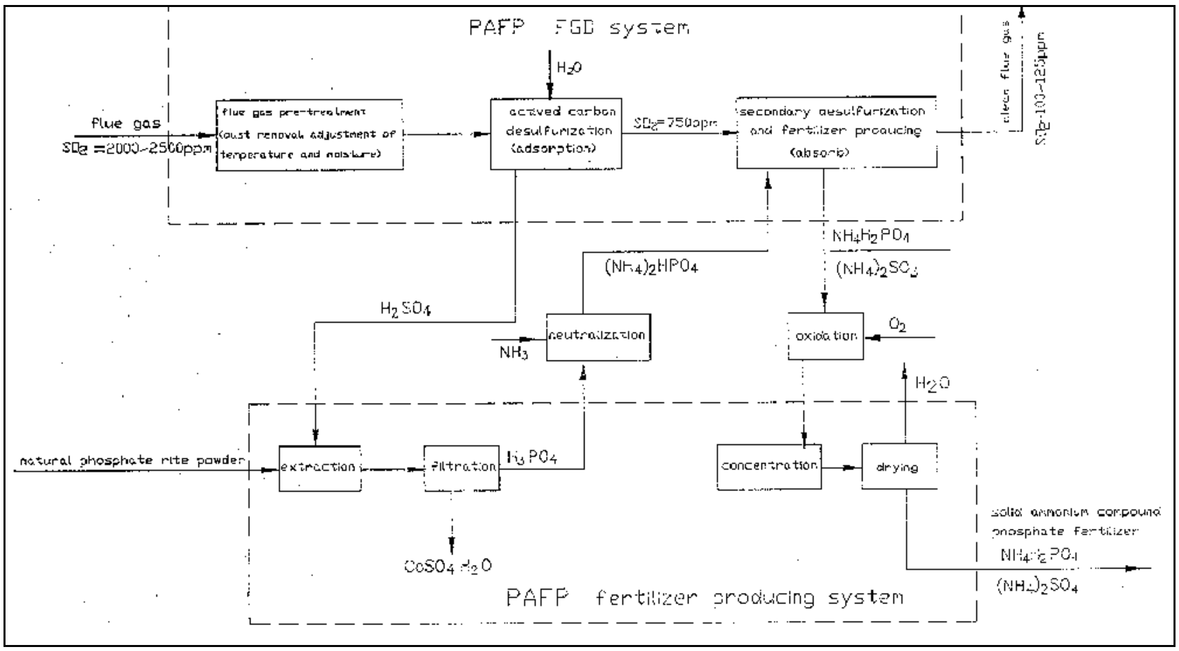

Figure 5. PAFP FGD flow diagram (Douba Thermal Power Plant, Sichuan)

The pilot test was finished in 1991 and is undergoing national appraisal. To further develop and popularize the technology, an industrial trial plant with a flue-gas treatment capacity of 100,000 Nm^3/h was built at the Douba Thermal Power Plant late in 1997. Whereas the secondary desulfurization process is complicated and expensive, the trial system uses only primary desulfurization, with a designed DeNOx efficiency of 70–75%. The byproduct is 30% dilute sulfuric acid, which can be used to react with iron selected from coal slag or other waste industrial iron to produce ferrous sulfide and iron oxide red. The 72-hour "acceptance operation" was completed in May 1998, and the main technical parameters are as follows: average SO_2 concentration at the inlet is 2960 ppm, average desulfurization efficiency is 73.5%, and flue-gas treatment capacity is 107,000 Nm^3/h. The absorbent for desulfurization can be used for a long time without additional absorbent.

The PAFP technology at Douba Thermal Power Plant was developed by Chinese technicians, and all the equipment for the trial system was made in China. Even though the problem of how to use the byproduct of dilute sulfuric acid has not been solved, PAFP contributes much to manufacturing FGD equipment in China, and to finding a highly efficient, economical FGD solution.

3.4 Semi-Dry Rotary Spray Desulfurization (LSD)

The LSD system at Baima Thermal Power Plant is the first large pilot desulfurization plant developed by Chinese technicians independently. It has a treatment capacity of 70,000 Nm^3/h, and occupies 600 m^2 of space. Now in operation, the pilot plant was built in January 1990, and after 2000 hours of continuous operation completed the appraisal organized by the National Environmental Protection Authority in January 1991.

The flue gas at the plant comes from #22 Boiler (200 MW) with a sulfur concentration of 3000 ppm, and a temperature of 150–160   C. The absorbent is solid quicklime with CaO content of 60–70%, which is ground and changed into slurry and sent into absorber. The outlet gas temperature is of 65–68   C. Ca/S is 1.4, and desulfurization efficiency is 80%. Since the desulfurization plant was put into operation in 1990, the average operating time has been about 5000 hours, operating capacity has been more than 92%, and the plant can be operated simultaneously with generating units. The cost for desulfurization is about US$0.1 to remove 1 kg of SO_2, which means US$0.0017 will be added for each kWh of power generated. Nine years of operating experience show that: the LSD system is simple and reliable, easy to operate and maintain, and occupies a small space with reliable desulfurization results. The limestone produced in China is suitable for the technology. Even though the desulfurization efficiency is relatively low, it is easy to manufacture all the equipment in China, and the LSD process lowers the investment and contributes much to the development of Chinese FGD technology..

3.5 Wet-Type Limestone-Gypsum FGD

The installed capacity of Huagneng Luohuang Thermal Power Plant is 4x360 MW. The coal for the plant is anthracite with high sulfur content from the Chongqing Songzhao Coal Mine; sulfur content of the raw coal is 3.5–5.0%. Annual SO_2 emissions will be about 200,000 tons if FGD measures are not taken.

The Phase I Project of the power plant 2x360 MW was put into operation in 1992. Two wet-type limestone-gypsum FGD systems produced by Mitsubishi Heavy Industries (Japan) were imported (Figure 7). The designed treatment capacity of each system is $108.7 \times 10^4 Nm^3/h$, with desulfurization efficiency of more than 90%. The clean flue gas will be reheated to 90   C and then go to the stack. Testing results show that the desulfurization efficiencies of the two systems are 95.9% and 96.7%, and the gypsum purities 93% and 93.4%.

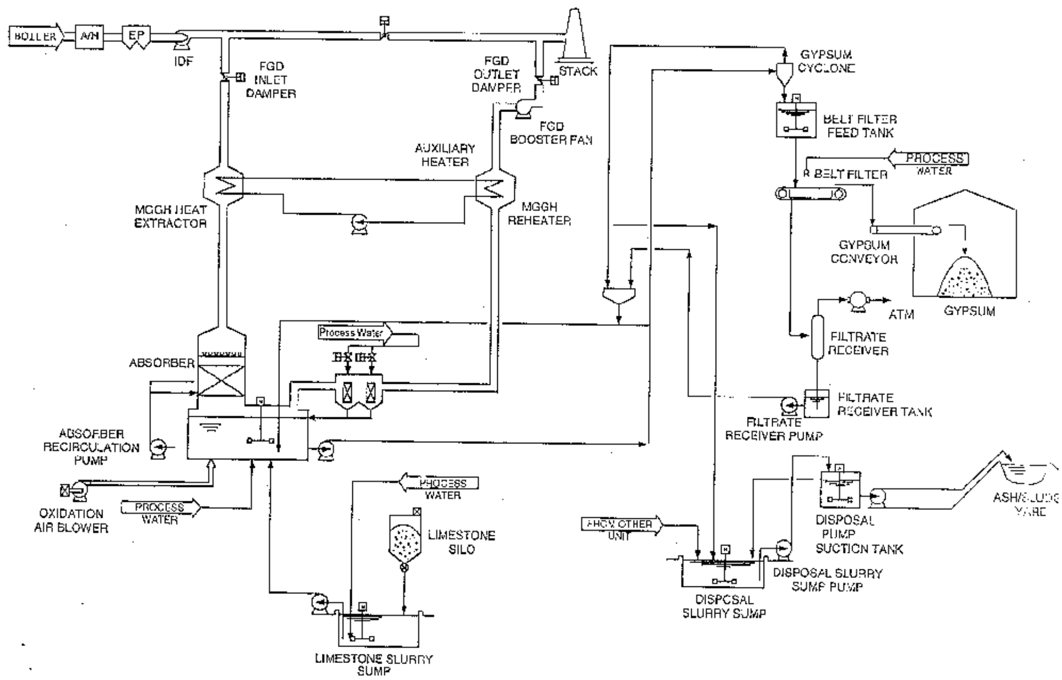

Figure 7. Wet limestone-gypsum FGD system (Huaneng Thermal Power Plant, Chongqing)

There are two main problems with the desulfurization systems in the Phase-I Project. One is that the temperature of the flue gas from the boiler is 20 C higher than the designed value, causing the temperature of the absorber inlet to be higher than its designed temperature, in turn affecting the normal operating performance of inside lining material of the absorber. Several technical upgrades, such as spraying water to lower the temperature, contribute to improving the utilization ratio of the FGD plant. The second problem is that many spare parts for the equipment must be imported, especially some easily damaged parts, making it difficult sometimes to guarantee normal operation.

The Phase-II Project of the power plant 2x360 MW was put into operation at the end of 1998. Two FGD systems were built that were similar to the Phase-I system supplied jointly by the Chinese and Japanese manufacturers. Based on the problems appeared in the Phase-I Project, and actual conditions in the Phase-II Project, some modifications were made for the Phase-II Project. First, the treated flue gas only takes 85% of total flue gas, and the DeNOx efficiency of Phase II is more than 80%, which can meet the goal of controlling SOx emissions. Second, change the grill filling scrubber of Phase-I Project into adverse current/current wise liquid tower, in this way guaranteeing higher desulfurization efficiency and avoiding the scaling and blocking of former scrubber, and improving the reliability of the system.

After the four FGD systems at Luohuang Thermal Power Plant were put into operation, they had the capacity to produce more than 4,000,000 tons of gypsum in one year. At present, gypsum is not utilized; instead, nearly all of it is sent to ash yards. Speeding the utilization of FGD-generated gypsum will lower the cost of desulfurization, and will help popularize limestone-gypsum technology in China.

4) THE PROSPECTS FOR FGD TECHNOLOGY IN SICHUAN

In the Fourth National Environmental Protection Conference held in July 1996, it was made clear that emphasis must be placed on tackling air pollution in the Acid Rain Control Area and the SO_2 Pollution Control Area (referred to as the “Two Controlling . At the same time, the government’s manner of regulating SO_2 emissions will be changed from controlling emission height and concentration, and charging for emissions, to controlling the quantity of emissions.

In January 1998, the State Council issued a file to make clear the dividing scheme for the Two Controlling Areas, as well as the control target and control manner. The State Power Corporation and Sichuan Provincial Government took action immediately, issuing several implementation schemes and plans for SO_2 emission control; these required that by the year 2000, SO_2 emissions from coal-fired power plants must meet the requirement. Inside the Two Controlling Areas, newly built coal-fired power plants must have FGD systems, and expansion of existing plants using coal with a sulfur content of more than 1% must incorporate FGD systems in steps by the year 2010. To further help control SO_2 pollution, the provincial government has placed restrictions on the mining and utilization of coal with high sulfur content. At the same time, SO_2 emission-charge areas have been enlarged from testing-charge areas to the whole acid-rain control area. Except for the Huayingshan Thermal Power Plant, coal-fired power plants of the SEPC must pay for SO_2 emissions, which is a big burden on these plants.

Given this situation, Sichuan must build more desulfurization plants in order to develop its economy, build new power plants, and operate existing coal-fired plants. This is a good opportunity for development of desulfurization technology in Sichuan. Research and equipment testing on the main desulfurization technologies available in the world have been done in Sichuan. In addition, the technologies introduced from foreign countries are being operated reliably and efficiently, and the digesting and absorption of these technologies has been carried out. Also, much experience has been gained in the operation of technologies developed by Chinese technicians. Owing to this preparation, the implementation of desulfurization at coal-fired power plants in Sichuan is basically possible, and with the support of policy, it is believed that further development of FGD will enter a new period and advance rapidly.

CFBC boilers, another of the main types of boilers used for environmental protection, have been operated safely and reliably in Sichuan for many years. Now, the ability to manufacture 100–MW CFBC boilers in China is available, and preparation work for manufacture of 300–MW CFBC boilers has also been done. In March 1998, the government approved construction of another 100–MW CFBC power-generating unit at the Yibin Thermal Power Plant; this is the first CFBC unit manufactured in China, and the project is undergoing a feasibility study now.

The government also approved construction of a 300–MW CFBC-boiler pilot project at the Baima Thermal Power Plant in Neijing City in order to promote development of CFBC technology in China; one 1025-t/h CFBC boiler and key parts will be imported, making Sichuan the trial location for large CFBC boilers in China. Given the low quality and high sulfur content of coal in Sichuan, as well as the meteorological and geological conditions and the location of principal coal-fired power plants, CFBC technology will be a mainstay of desulfurization for coal-fired power plants using high-sulfur coal.

However, considering the big investment and long construction period, deciding on projects must be prudent. .

Limestone-gypsum technology is the most mature and popularized of the commercial desulfurization technologies in the world. Given the large investment and long construction period required for this technology, and the difficulty in utilization of its byproduct, it is usually used on large generating units. In spite of these drawbacks, however, its maturity and good record for large generating units assures a good market share. Limestone-gypsum technology has been selected for the first phase of a desulfurization project of 2x300 MW at the Guangan Thermal Power Plant; this project is undergoing a feasibility study. Also, design for a limestone-gypsum FGD project at the Chongqing Thermal Power Plant (formerly controlled by SEPC) is under way.

The advantages of semi-dry type desulfurization technology are that it is technically mature and requires only a small space and small investment; these characteristics make it very suitable for existing coal-fired generating units that are badly in need of FGD plants. The feasibility study and design has been approved for a desulfurization and dust-removal project at the #22 boiler at Baima Thermal Power Plant; a semi-dry type of gas phase suspension absorbing desulfurization technology will be adopted. If a breakthrough on utilization of ash/slag can be realized, this technology will be used more widely.

The industrial test of EBA technology has been successfully verified, and most of the equipment can be manufactured in China. After correcting problems at the existing trial plant, finishing the cultivation test and getting a license for the fertilizer byproduct, the technology will have good prospects for 200–MW, 300–MW and 600–MW generating units. The advantages of desulfurization and DeNOx occurring simultaneously are that no waste water or slag is produced. Also, using the byproduct as fertilizer is unique, and makes the technology very suitable for coal-fired power plants that have an ammonia supply and for power plants that are near big cities.

The trial of PAFP equipment is still under way, and all the equipment can be manufactured in China. The big problem for popularization of this technology is finding a use for its byproduct, dilute sulfuric acid, which is under study. PAFP gives new vitality to traditional ammonia-based desulfurization technology. Even though the preliminary results of a pilot test of PAFP have been obtained, it is necessary to do further industrial testing if the technology wants to gain more market share.

5) CONCLUSION

A shortage of funds is the key problem for development of desulfurization in coal-fired power plants in Sichuan. Considering that a large investment is needed to build a desulfurization plant, priority is always given to technologies requiring smaller investments. The best solution is to speed up the adoption of high-efficiency desulfurization technologies introduced from foreign countries, and to manufacture more equipment in China.

In the future, the shortage of funds for desulfurization will be alleviated as more and more investment and financing are available, but there is still a big gap to be bridged. For the several desulfurization projects that will be constructed in the near future, imported equipment and introduced technologies will still play an important role to guarantee the operational reliability of FGD. Therefore, the most important work for us is to speed up the pace of equipment manufacturing in China, and to promote the commercialization of desulfurization technologies developed by Chinese technicians, such as LSD, PAFP, and ammonia-based desulfurization.

The utilization or disposition of ash/slag from desulfurization plants is another big problem affecting development of the technology. Up to now, studies of this problem have not had good progress, but further studies are being undertaken, and a breakthrough is expected very soon.

In summary, Sichuan basically has been developed as an example base for FGD technology in China, and will be kept moving forward. We hope that in the near future, the technologies of SOx control will be further improved, and will greatly change the acid rain situation in Sichuan.